CLAIMS

I claim:

1. A method for analyzing seismic data, comprising:

selecting a seismic data volume from a subsurface region of interest, said seismic data volume comprising seismic data sample points;

declaring a geologic time volume having data storage locations corresponding to said seismic data sample points;

obtaining geologic times corresponding to at least a portion of said seismic data sample points; and

storing said geologic times in said geologic time volume in data storage locations corresponding to said at least a portion of said seismic data sample points.

2. The method of claim 1 wherein said geologic times comprise estimated geologic times.

3. The method of claim 1 wherein said geologic times comprise pseudo geologic times.

4. The method of claim 2 wherein said estimated geologic times are obtained from available data for locations within said subsurface region of interest.

5. The method of claim 1 wherein said seismic data volume is a three dimensional seismic data volume.

6. The method of claim 1 wherein said seismic data volume is a two dimensional seismic data volume.

7. The method of claim 1 wherein storing said geologic times comprises storing said geologic times on a magnetic storage medium.

8. The method of claim 1 wherein storing said geologic times comprises storing said geologic times on an optical storage medium.

9. The method of claim 1 wherein storing said geologic times comprises storing said geologic times on a computer random access memory.

10. The method of claim 4 wherein said available data comprise data from at least one wellbore.

11. The method of claim 10 wherein said data from at least one wellbore comprise measurements made on rock samples from a wellbore.

12. The method of claim 4 further comprising interpolating geologic times for locations within said seismic data volume between locations for which geologic time data are available.

13. The method of claim 12 wherein interpolation of geologic times for locations within said seismic data volume between locations for which geologic time data are available comprises unwrapping instantaneous phase of seismic data.

14. The method of claim 1 wherein said geologic times are obtained from horizons which have been identified in said seismic data volume.

15. The method of claim 14 wherein all seismic data sample points corresponding to at least one of said horizons are assigned the same geologic time.

16. The method of claim 14 wherein a pseudo geologic time is assigned to each said identified horizon.

17. The method of claim 14 wherein an estimated geologic time is assigned to at least one identified horizon on the basis of available geologic time data.

18. The method of claim 14 further comprising interpolating geologic time between locations of identified horizons.

19. The method of claim 18 wherein said interpolation comprises unwrapping instantaneous phase of seismic data.

20 The method of claim 3 wherein obtaining estimated geologic times comprises unwrapping instantaneous phase of seismic data.

21. A method for analyzing seismic data, comprising:

selecting a seismic data volume from a subsurface region of interest, said seismic data volume comprising seismic data sample points;

declaring a geologic time volume having data storage locations corresponding to said seismic data sample points;

selecting a plurality of identified horizons from said seismic data volume;

assigning a geologic time to each said identified horizon; and

storing said geologic time assigned to each said identified horizon in storage locations in said geologic time volume corresponding to locations of said identified horizons in said seismic data volume; thereby generating a geologic time volume.

22. The method of claim 21 wherein all seismic data sample points corresponding to at least one of said horizons are assigned the same geologic time.

23. The method of claim 21 wherein a pseudo geologic time is assigned to each said identified horizon.

24. The method of claim 21 wherein at least one of said identified horizons is an unconformity and said assigned geologic time varies laterally along said horizon.

25. The method of claim 21 wherein estimated geologic time is assigned to at least one identified horizon on the basis of available geologic time data.

26. The method of claim 21 further comprising interpolating geologic time between locations of identified horizons.

27. The method of claim 26 wherein said interpolation comprises unwrapping instantaneous phase of seismic data.

28. A method for analyzing seismic data, comprising:

selecting a seismic data volume comprising spatially related seismic data traces, each seismic data trace comprising seismic data sample points;

calculating instantaneous phase for a plurality of said seismic data traces;

unwrapping the calculated instantaneous phase for said plurality of seismic data traces;

assigning geologic times to locations along said seismic data traces, said geologic times being related to unwrapped phase at said locations; and

storing said assigned geologic times in selected storage locations corresponding to said locations along said seismic data traces, thereby generating a geologic time volume.

29. The method of claim 28 wherein unwrapping instantaneous phase of a seismic data trace comprises:

(a) determining cycle numbers for said seismic data traces; and

(b) determining unwrapped phase for said seismic data traces, said unwrapped phase and cycle numbers being related to instantaneous phase according to the following relationship:

$$\phi = IP + 360n$$

where: ϕ = unwrapped phase (in degrees);

IP = instantaneous phase (in degrees); and

n = cycle number.

30. The method of claim 28 further comprising determining locations in the unwrapped instantaneous phase where the change in unwrapped phase is anomalous.

31. The method of claim 30 wherein at least one of said locations is the location of an unconformity.

32. The method of claim 30 wherein at least one of said locations is the location of a fault.

33. The method of claim 30 wherein at least one of said locations is the location of a fluid contact.

34. The method of claim 30 wherein at least one of said locations is the location of source generated noise interference.

35. The method of claim 30 wherein at least one of said locations is the location of a phase unwrapping error.

36. The method of claim 28 further comprising applying a constraint to the instantaneous phase unwrapping to limit the number of successive sample times of a seismic data trace for which the first derivative of the unwrapped instantaneous phase may be negative.

37. The method of claim 36 wherein the constraint includes verifying that the instantaneous phase was generated so that it increases with seismic signal travel time.

38. The method of claim 36 wherein the constraint includes determining locations where the derivative of the instantaneous phase is negative for at least two vertically consecutive sample points and minimizing the effect of said locations on phase unwrapping results.

39. The method of claim 28 further comprising applying a constraint to the instantaneous phase unwrapping which utilizes disturbances in the local continuity of the instantaneous phase to determine the best location for branch cuts used by a phase unwrapping algorithm.

40. The method of claim 28 further comprising applying a constraint to the instantaneous phase unwrapping which utilizes disturbances in the local continuity of the instantaneous phase to determine low quality zones used by a phase unwrapping algorithm.

41. A method for analyzing seismic data, comprising:

selecting a seismic data volume comprising seismic data sample points;

selecting a plurality of adjoining subvolumes from said seismic data volume;

for each subvolume, obtaining geologic times corresponding to at least a portion of said seismic data sample points;

reconciling geologic times corresponding to seismic data sample points in adjoining locations of said subvolumes; and

for each subvolume, storing said reconciled geologic times in data storage locations corresponding to said at least a portion of said seismic data sample points; thereby generating a geologic time volume for each subvolume

42. The method of claim 41 wherein said adjoining subvolumes are contiguous subvolumes.

43. The method of claim 41 wherein said adjoining subvolumes are overlapping subvolumes.

44. The method of claim 41 wherein reconciling geologic times corresponding to seismic data sample points in adjoining locations of said subvolumes further comprises:

comparing instantaneous phase and cycle numbers in said adjoining locations;

propagating instantaneous phase modifications into adjoining subvolumes;

comparing locations of cycle boundaries in said adjoining locations;

moving and adding new boundaries into adjoining subvolumes;

determining if cycle numbers are the same in said adjoining locations;

selecting the highest cycle number if cycle numbers are different at said adjoining locations; and

propagating any changes in cycle numbers into adjoining subvolumes.

45. A method for analyzing seismic data, comprising:

selecting a seismic data volume comprising seismic data sample points;

selecting a plurality of adjoining subvolumes from said seismic data volume;

for each subvolume, obtaining geologic times corresponding to at least a portion of said seismic data sample points;

reconciling geologic times corresponding to seismic data sample points in adjoining locations of said subvolumes; and

storing said reconciled geologic times in data storage locations corresponding to said selected seismic data volume; thereby generating a geologic time volume

46. The method of claim 45 wherein reconciled geologic times from each of said plurality of adjoining subvolumes are stored in a single geologic time volume.

47. The method of claim 45 wherein said adjoining subvolumes are contiguous subvolumes.

48. The method of claim 45 wherein said adjoining subvolumes are overlapping subvolumes.

49. The method of claim 45 wherein reconciling geologic times corresponding to seismic data sample points in adjoining locations of said subvolumes further comprises:

comparing instantaneous phase and cycle numbers in said adjoining locations;

propagating instantaneous phase modifications into adjoining subvolumes;

comparing locations of cycle boundaries in said adjoining locations;

moving and adding new boundaries into adjoining subvolumes;

determining if cycle numbers are the same in said adjoining locations;

selecting the highest cycle number if cycle numbers are different at said adjoining locations; and

propagating any changes in cycle numbers into adjoining subvolumes.

50. A method for analyzing seismic data, comprising:

selecting a seismic data volume comprising seismic data sample points;

declaring a geologic time volume having data storage locations;

obtaining geologic times corresponding to at least a portion of said seismic data sample points, thereby generating assembled geologic time data;

applying data compression techniques to said assembled geologic time data, thereby generating compressed geologic time data; and

storing said compressed geologic time data in said data storage locations to enable geologic times corresponding to said at least a portion of said seismic data sample points to be retrieved from said data storage locations.

51. The method of claim 50 wherein representations of geologic time are stored in said geologic time volume as a single value.

52. The method of claim 50 wherein representations of geologic time are stored in said geologic time volume as a combination of at least two values.

53. The method of claim 52 wherein said at least two values comprise cycle number and instantaneous phase.

54. The method of claim 53 wherein cycle numbers are repeated to create wrapped cycle numbers.

55. The method of claim 54 wherein cycle number wrap surfaces are stored so that the spatial position of the cycle number wrap surface and the number of times the cycle values have wrapped are stored.

56. The method of claim 54 further comprising determining the unwrapped cycle number of a point from the wrapped cycle number and the number of times the cycle values have wrapped.

57. The method of claim 1 wherein representations of pseudo geologic time are stored in said geologic time volume and other representations are stored in said geologic time volume to calibrate the pseudo geologic time to measured geologic time.

58. A digital computer programmed to utilize seismic data to perform a process comprising the steps of:

selecting a seismic data volume from a subsurface region of interest, said seismic data volume comprising seismic data sample points;

declaring a geologic time volume having data storage locations corresponding to said seismic data sample points;

obtaining geologic times corresponding to at least a portion of said seismic data sample points; and

storing said geologic times in said geologic time volume in data storage locations corresponding to said at least a portion of said seismic data sample points.

59. A device which is readable by a digital computer having instructions defining the following process and instructions to the computer to perform said process:

selecting a seismic data volume from a subsurface region of interest, said seismic data volume comprising seismic data sample points;

declaring a geologic time volume having data storage locations corresponding to said seismic data sample points;

obtaining geologic times corresponding to at least a portion of said seismic data sample points; and

storing said geologic times in said geologic time volume in data storage locations corresponding to said at least a portion of said seismic data sample points.

60. A digital computer programmed to utilize seismic data to perform a process comprising the steps of:

electing a seismic data volume from a subsurface region of interest, said seismic data volume comprising seismic data sample points;

declaring a geologic time volume having data storage locations corresponding to said seismic data sample points;

selecting a plurality of identified horizons from said seismic data volume;

assigning a geologic time to each said identified horizon; and

storing said geologic time assigned to each said identified horizon in storage locations in said geologic time volume corresponding to locations of said identified horizons in said seismic data volume; thereby generating a geologic time volume.

61. A device which is readable by a digital computer having instructions defining the following process and instructions to the computer to perform said process:

selecting a seismic data volume from a subsurface region of interest, said seismic data volume comprising seismic data sample points;

declaring a geologic time volume having data storage locations corresponding to said seismic data sample points;

selecting a plurality of identified horizons from said seismic data volume;

assigning a geologic time to each said identified horizon; and

storing said geologic time assigned to each said identified horizon in storage locations in said geologic time volume corresponding to locations of said identified horizons in said seismic data volume; thereby generating a geologic time volume.

62. A digital computer programmed to utilize seismic data to perform a process comprising the steps of:

selecting a seismic data volume comprising spatially related seismic data traces, each seismic data trace comprising seismic data sample points;

calculating instantaneous phase for a plurality of said seismic data traces;

unwrapping the calculated instantaneous phase for said plurality of seismic data traces;

assigning geologic times to locations along said seismic data traces, said geologic times being related to unwrapped phase at said locations; and

storing said assigned geologic times in selected storage locations corresponding to said locations along said seismic data traces, thereby generating a geologic time volume.

63. A device which is readable by a digital computer having instructions defining the following process and instructions to the computer to perform said process:

selecting a seismic data volume comprising spatially related seismic data traces, each seismic data trace comprising seismic data sample points;

calculating instantaneous phase for a plurality of said seismic data traces;

unwrapping the calculated instantaneous phase for said plurality of seismic data traces;

assigning geologic times to locations along said seismic data traces, said geologic times being related to unwrapped phase at said locations; and

storing said assigned geologic times in selected storage locations corresponding to said locations along said seismic data traces, thereby generating a geologic time volume.